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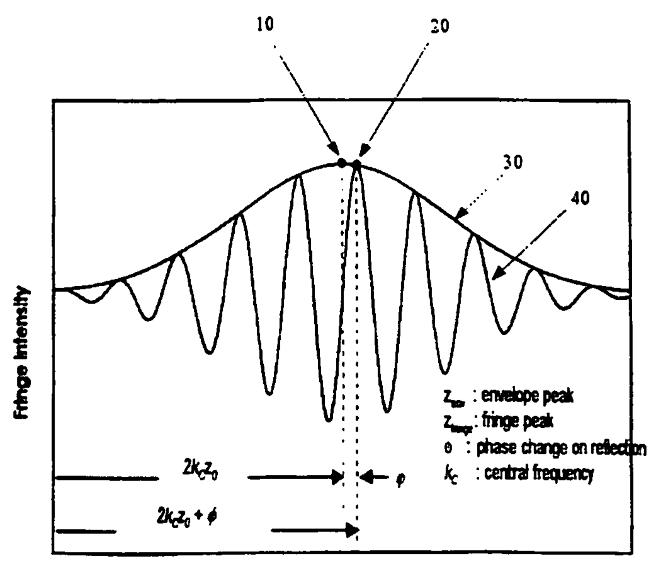
(54) Title: A METHOD AND APPARATUS OF TWO WAVELENGTH INTERFEROMETRY FOR MEASURING ACCURATE HEIGHT OF SMALL STEP COMPOSED OF TWO DIFFERENT MATERIALS



(57) Abstract: This invention is on a measurement method and apparatus for measuring the accurate height of a very small step composed of two different flat materials. In this method, two wavelength-white light interferometry is used and the measuring error caused by the change in phase difference by two materials is compensated by a unique equation.

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A method and apparatus of two wavelength interferometry for measuring accurate height of small step composed of two different materials.

Technical Field

The present invention relates to a measurement method capable of compensating an error generated when the height of a step composed of different materials is measured using two-wavelength white-light interferometry. Specifically, the invention relates to a measurement method capable of mathematically modeling the effect of the difference in phase change caused by different metals on the measuring error and interpreting the mathematical expression, thereby compensating the measuring error with only one-time measurement.

Background Art

The step height of a material is measured using a monochrome light (single wavelength) scanning interferometer or a white light (multi-wavelength) scanning interferometer. In general, phase change occurs when illuminating light is inputted into a material and then reflected. In case that a step is composed of the same kind of materials, the measuring error caused by phase change is not generated because phase changes by the two materials are identical to each other. When the step is composed of two different materials, however, phase changes by the materials are different from each other so that the height of the step composed of the two different materials cannot be accurately measured. In case where the height of a step composed of different materials is measured using the monochrome light scanning interferometer, the difference in phase change of the materials for the frequency of illuminating light use was confirmed in advance and the confirmed phase change difference was reflected on the measured result. In this case, however, compensation can be carried out only when the frequency of the illuminating

light used and phase change of each material are known and, if the material is changed or the frequency of the illuminating light varies, the phase change occurs differently to make the compensation difficult. In addition, accurate phase change rate cannot be calculated when white light is used as the illuminating light. In this case, the phase change rate is predicted on an average to compensate so that accurate compensation is difficult to perform. Thus, the white light is not used as the illuminating light in most cases.

On the other hand, in case of a step composed of the same kind of materials, the white light is often used because unnecessary stray diffraction is not generated due to short coherent range (range where interference occurs) thereof. The basic principle applied to this is that the position of a measurement surface or a reference mirror is accurately moved in the direction of an optical axis to obtain a transfer distance to a position at which the intensity of interferogram is the highest and the obtained transfer distance is converted into the height of the measurement surface. Compared to monochrome laser light, the coherent range of the white light is limited to several micrometers so that the position of the envelope peak is clear. Thus, problems with respect to 2π ambiguity are not generated when the absolute phase of the measurement surface is calculated. In addition, superior interferogram from which stray diffraction was removed can be acquired because unnecessary diffraction is not generated from an optical system. The white-light scanning interferometer is being widely studied in response to the extension of industrial demand requiring precise examination of a surface and the recent rapid improvement of computation capability of a microcomputer.

As described above, while the white-light interferometer is widely used for measuring the height of a step composed of the same kind of metal materials owing to its advantage of short coherent range, it is not suitable for different kinds of metal materials because of the difference in phase change in the different metals. That is, when the height of a step composed of different metals is measured using the white-light interferometer,

the measuring error of 10-40nm is brought about due to the difference in phase change generated when the white light is reflected from the different metals. The error is compensated using monochrome light in most cases, which requires a difficult correction process. Furthermore, in case where the height of the step composed of different metals is measured using the white-light scanning interferometer, the phase change difference is generated in all wavelengths due to the different metals so that analysis becomes very complicated. Accordingly, measurement methods using illuminating light having a wide wavelength band such as the white light are barely applied to the measurement of the height of a step composed of different materials.

Disclosure of Invention

An object of the present invention is to provide an algorithm for overcoming the difference in phase change generated in different materials while making effective use of the advantage of white light in the measurement of the height of a step composed of the different materials using the white-light scanning interferometer.

Another object of the present invention is to provide a measurement method capable of realizing the algorithm and a measurement system to which the measurement method is applied.

To accomplish the objects of the present invention, the invention analyzes phase change that occurs when the height of a step composed of different materials is measured with the white-light scanning interferometer, develops mathematical modeling for overcoming the phase change, and proposes a measurement method and system for realizing the modeled algorithm, thereby realizing a two-wavelength white-light interferometer capable of compensating a step composed of the different materials.

Brief Description of the Drawings

FIG. 1 illustrates the fringe peak and envelope peak of a white-light interferogram;

FIG. 2 illustrates the height h of a step composed of a metal A and a metal B in

monochrome light interferometry;

FIG. 3 illustrates phase changes of lights reflected from metal surfaces according to wavelengths;

FIG. 4A illustrates analysis of the error caused by the envelope peak, $z_\phi(=\frac{1}{2}\frac{d_\phi}{dk})$ (phase change error);

FIG. 4B illustrates analysis of the error caused by the envelope peak, $z_\phi(=\frac{1}{2}\frac{d_\phi}{dk})$ (result of calculation of phase change error);

FIG. 5A illustrates the spectrum of the white light interferogram using Fourier transform (white-light interferogram);

FIG. 5B illustrates the spectrum of the white-light interferogram using Fourier transform (result of Fourier transform);

FIG. 6 illustrates a configuration of a two-wavelength white-light interferometer;

FIG. 7A illustrates analysis of a two-wavelength white-light interferogram (two-wavelength white-light interferogram : I(z));

FIG. 7B illustrates analysis of the two-wavelength white-light interferogram (frequency conversion of the two-wavelength white-light interferogram : J(k)=FFT[I(z)]); and

FIG. 8 illustrates results of compensation of the 94nm VLSI standard step sample using the two-wavelength white-light interferometer (h=95.3nm).

Best mode for Carrying Out the Invention

The two-wavelength white-light interferometer can be realized through various interference optical systems including Micheolson, Mirau, Linnik and so on. A method of measuring the height of a step composed of different metals through the two-wavelength white-light interferometer to which Micheolson interference optical system is applied is explained below. Here, it is assumed that the numerical aperture (NA) value of the optical

system is small, and parameters are defined as follows.

Z_0 : Actual position of an object to be measured

Z_m : Peak of a white-light interferogram

Z_{env} : Envelope peak of the white-light interferogram ($Z_{env} = Z_m$)

Z_{fringe} : Fringe peak of the white-light interferogram ($z_{fringe} = z_m - \phi_m / 2k_0$)

Z_ϕ : Error of the envelope peak caused by phase change of a metal ($z_\phi (= \frac{1}{2}\frac{d_\phi}{dk})$)

ϕ_m : Phase value appearing in the white-light interferogram

h : True value of the height of a step composed of metals

H : Step height value measured using the fringe peak of the white-light interferogram

h_1: Step height value measured using the monochrome light interferometry at frequency k_1 (wavelength λ_1)

h_2: Step height value measured using the monochrome light interferometry at frequency k_2 (wavelength λ_2)

Δh : $h_2 - h_1$

k_0: Central frequency of white light ($k_0 = 2\pi/\lambda_0$)

k_1: Frequency of light for measuring the step height h_1 ($k_1 = 2\pi/\lambda_1$)

k_2: Frequency of light for measuring the step height h_2 ($k_2 = 2\pi/\lambda_2$)

When it is assumed that the numerical aperture (NA) value is as small as it can be ignored and the height of the object to be measured is z_0, a variation in the optical intensity of interferogram with respect to a scan distance z is represented by the following equation. (Reference : "The Mirau correlation microscope" by G. Kino and S. Chim, App. Opt, 29(26), 3775-3783 (1990))

$$I(z) = I_0 \int_{k_0 - Aeltak/2}^{k_0 + Aeltak/2} [1 + \gamma(k)\cos(2k(z - z_0) + \phi(k))]F(k)dk \qquad \text{(Equation 1)}$$

In Equation 1, $r(k)$ is reflectivity, $\phi(k)$ is phase change generated when the metal

reflects light, $F(k)$ is the spectrum of light, k_0 is the central frequency of the light ($k_0 = 2\pi / \lambda_0, \lambda_0$ is the central wavelength of the light) and Δk is the frequency band of white-light used. The phase change $\phi(k)$ is induced by Fresnel equation. When it is assumed that the light is inputted into the object to be measured perpendicularly, the reflectivity is as follows.

$$r = \frac{n_i - n_t}{n_i + n_t} \qquad \text{(Equation 2)}$$

In Equation 2, n_i, n_t are refractive indexes of an incident material and a reflecting material, respectively. In general, the incident material is air whose reflective index n_i is 1. In case that the reflecting material is a metal, the metal has energy loss according to the photoelectric effect caused by reflection of light so that the refractive index of the metal is represented by $n_t = n - ik$ that is a complex number. Due to this refractive index of the complex number of the metal, the phase change ϕ is determined as follows.

$$\tan\phi = \frac{2k}{n^2 + k^2 - 1} \qquad \text{(Equation 3)}$$

If Equation 1 is integrated in consideration of the phase change of the Equation 3, general white-light interferogram equation as described below is acquired.

$$I(z) = g(z - z_m)\cos(2K_0(z - z_m) + \phi_m) \qquad \text{(Equation 4)}$$

In Equation 4, a background light component I_0 is omitted for the simplification of the equation, and $g(z - z_m)$ is the envelope function and ϕ_m is the average value of phase changes for the white-light wavelength band. The white-light interferogram reproduced on the basis of Equation 4 is represented as shown in FIG. 1. Accordingly, if all of peaks of the interferogram generated in the overall measurement range are detected, the three-dimensional shape of the object to be measured can be restored. As shown in FIG. 1, the white-light interferogram includes the envelope peak that is the highest point of the envelope function and the fringe peak that is the maximum value of the interferogram itself. The envelope peak z_{env} and the fringe peak z_{fringe} are represented

as $z_{env} = z_m$ and $z_{fringe} = z_m - \phi_m / 2k_0$, respectively. In case where the fringe peaks are applied to a conventional measurement method according to an optical phase interferometry to measure the height h of a step composed of different metals A and B, as shown in FIG, the measuring error of $(\phi^B - \phi^A)/2k_0$ is generated. The error of the fringe peaks is corrected by grasping characteristics of the object to be measured and then correcting phase change using data of an optical handbook or by using a conventional experimental method ("Effects of phase changes on reflection and their wavelength dependence in optical profilometry" by T. Doi and K. Toyoda, App. Opt, 36, 7157 (1997)). These correction methods require excessively large quantity of calculations. In addition, it is difficult to apply the methods to the actual object to be measured. Meanwhile, studies on the error of the envelope peak caused by a step height of different metals have been made only when monochrome light is used as the illuminating light and the optical system has a high numerical aperture value. Thus, there have been hardly carried out studies on the case of employing the white light as the illuminating light because of complicate characteristic that phase change depends on wavelength.

It is known that the envelope peak largely depends on the spectrum of light, reflectivity and phase change of the object to be measured and the numerical aperture value of the optical system. To investigate effects of phase change on the envelope peak of the white-light interferogram, the interference term $\phi(k)$ in Equation 1 where the numerical aperture of the optical system is assumed to be very small is defined as follows.

$$\Phi(k) = \phi(k) + 2k(z - z_0) \qquad \text{(Equation 5)}$$

$\phi(k)$ represents the phase change of the object to be measured according to wavelengths. If $\phi(k)$ is a constant, the envelope peak z_{env} becomes identical to the position of the object, z_0. However, the phase change $\phi(k)$ is intensive according to wavelengths, and variations of representative metals with respect to k are shown in FIG. 3.

(Reference : Edward D. Palik, Handbook of Optical Constants of Solids Vol I, Academic Press, (1985)). Referring to FIG. 3, it can be confirmed that the phase change $\phi(k)$ is linear without having a sharp change in the visual ray range. From this characteristic, the phase change $\phi(k)$ can be assumed as follows.

$$\phi(k) \cong \phi(k_0) + (k - k_0)\frac{d\phi}{dk} \qquad \text{(Equation 6)}$$

When Equation 6 is introduced into Equation 5, the following result is obtained.

$$\phi(k) \cong \phi(k_0) - k_0(\frac{d\phi}{dk}) + 2k(z - (z_0 - \frac{1}{2}\frac{d\phi}{dk})) \qquad \text{(Equation 7)}$$

If it is assumed that the interference term $\Phi(k)$, the spectrum distribution of the light, F(k), and reflectivity $\gamma(k)$ induced to Equation 7 are not sharply changed, the white-light interferogram represented by Equation 1 is generalized into Equation 4. However, as confirmed in the interference term $\Phi(k)$ of the following Equation 8, the position of the object, z_0, is moved by the slope component of phase change with respect to k, $0.5d\phi/dk$. From this, the envelope peak z_m has the value corresponding to the movement from the position of the object, z_0, to the phase change rate z_ϕ as represented in Equation 8.

$$z_m = z_0 - \frac{1}{2}\frac{d\phi}{dk} = z_0 - z_\phi \qquad \text{(Equation 8)}$$

Consequently, the movement value z_ϕ acts as an error of the envelope peak. Due to this, the error of $(d_\phi^A/dk - d_\phi^B/dk)/2$ is generated when the height h of the step composed of the different metals A and B is measured using the envelope peak.

The present invention proposes a self compensation method for compensating the aforementioned error of the envelope peak caused by the phase change rate and shows results obtained by applying this compensation method to actual measurements below.

The measuring error of the envelope peak, $(d_\phi^A/dk - d_\phi^B/dk)/2$, generated

when the step height h is measured, has the physical meaning as shown in FIG. 4A. If the phase changes of the metals A and B forming the step with respect to k is assumed as shown in FIG. 4A, it can be confirmed that the measuring error generated in this case is caused by a difference between the slopes of phase change of the two metals.

Accordingly, if the phase change slope difference is mathematically represented and analyzed to correct the error caused by the phase change, the height of the step composed of the different metals can be accurately measured.

The measurement and correction of the phase change difference start with setting the minimum frequency k_1 and the maximum frequency k_2 from the frequency band of the white light. Here, $k_1 < k_2$. The frequency k defined in the present invention is a wavenumber and $k = 2\pi / \lambda$. The first step of error correction is explained below.

When the height of a step composed of metals is measured using the two frequencies k_1 and k_2 through the monochrome light interferometry, the step height h_1 measured by the frequency k_1 and the step height h_2 measured by the frequency k_2 are represented by the actual step height h and the following Equation 9.

$$h_1 = h - \frac{\phi_1^A - \phi_1^B}{k_1}, \qquad h_2 = h - \frac{\phi_2^A - \phi_2^B}{k_2} \qquad \text{(Equation 9)}$$

In Equation 9, the upper added letters A and B represent phase changes generated in the metals A and B, respectively, and the lower added numerals 1 and 2 mean the measured results in the spectrum frequencies k_1 and k_2 of the light, respectively. Since the phase changes ϕ_1^A, ϕ_1^B, ϕ_2^A and ϕ_2^B are unknown values, the values h_1 and h_2 measured according to the monochrome light interferometry have results different from the actual step height h.

In the second step of the error correction, the monochrome light filter is removed and the step height is measured using the envelope peak of the white-light scanning

interferometry. Here, the measured result is represented as H. For analysis of the measured result H, the error value z_ϕ of the envelope peak, defined by Equation 8, is simplified as follows.

$$z_\phi \equiv \frac{1}{2}\frac{d\phi}{dk} \cong \frac{1}{2}\frac{\phi_2 - \phi_1}{k_2 - k_1} \qquad \text{(Equation 10)}$$

When the phase change error z_ϕ assumed by Equation 10 is employed, the measured step height H of the two materials A and B using the envelope peak z_m is represented as follows.

$$H = h - \frac{1}{2}\frac{(\phi_2{}^A - \phi_1{}^A) - (\phi_2{}^B - \phi_1{}^B)}{k_2 - k_1} \qquad \text{(Equation 11)}$$

The point of the phase change correction method is to compensate the error term of the envelope peak represented in Equation 11 using the step height values h_1 and h_2 obtained by the monochrome light interferometry. For this, the difference between the step heights in Equation 9 is represented by the following Equation 12 by introducing $\Delta\phi$.

$$\Delta h = h_2 - h_1 \cong -\frac{1}{k_0}[(\phi_2{}^A - \phi_1{}^A) - (\phi_2{}^B - \phi_1{}^B)] \qquad \text{(Equation 12)}$$

where k_0 is the central frequency of the light.

In Equation 12, k_1 and k_2 are replaced by k_0 for simplification of the equation. It is known that the error caused by the replacement does not affect the measurement and explanation about this is omitted. When Equation 12 is introduced into Equation 11, the following step height calculation equation is obtained.

$$h = H - \frac{1}{2}\frac{k_0(h_2 - h_1)}{k_2 - k_1} \qquad \text{(Equation 13)}$$

From Equation 13, it can be confirmed that the step height h of the different metals is accurately measured using the results h_1 and h_2 measured by the monochrome light interferometry and the measured result H obtained from the envelope peak of the white-

light scanning interferometer. As shown in FIG. 4B, $-\frac{1}{2}(d_\phi{}^A / dk - d_\phi{}^B / dk)$ represented as the phase change difference can be easily obtained using the errors of the step height, $(\phi_1{}^A - \phi_1{}^B)/k_1$ and $(\phi_2{}^A - \phi_2{}^B)/k_2$, measured at the two frequencies k_1 and k_2. However, the correction method using the monochrome light interferometry, described above, requires three-time measurements so that the measurement operations become complicated. Thus, an external environmental variation occurring during the measurements may become a measuring error.

As shown in FIG. 1, the fringe peak among the peaks of the white-light interferogram is decided by the phase of the interferogram, ϕ_m, which indicates the maximum intensity position of the interferogram. If the frequency band Δk of the white light used becomes narrow, the correlation distance of the interferogram is increased in the space so that the interference range becomes wide. In this case, the fringe peak of the white-light interferogram becomes identical to the fringe peak of the monochrome light interferometer. Accordingly, the fringe peak of the white-light interferogram can be analyzed as the average position of fringe peaks of all wavelengths within the frequency band Δk, and the phase change $\phi(k)$ with respect to the frequency of the light in Equation 1 means integration for the section of the frequency band Δk.

As shown in FIG. 5, if the measured white-light interferogram is dispersed using Fourier transform, the phases $\phi(k_1)$ and $\phi(k_2)$ can be calculated at the specific frequencies k_1 and k_2. Also, it can be analogized that and the heights h_1 and h_2 required for Equation 13 are substituted by the calculated phase values. Consequently, when a single white-light interferogram is dispersed, two fringe peaks and one envelope peak can be calculated simultaneously and the accurate metal step-height h can be measured using Equation 13. When a general white-light interferogram is dispersed, however, the interferogram is distributed all over the visual ray range, as shown in FIG.

5B, so that calculation of the phase of a specific wavelength component is easily affected by external disturbance. To overcome this shortcoming, two-wavelength white-light interferometry using two lights are applied, as shown in FIG. 6.

An apparatus using the two white lights having different central wavelengths, shown in FIG. 6, is roughly described. Lights emitted from the two white light sources 100 and 110 having central wavelengths λ_1 and λ_2, respectively are inputted into an optical combiner 120. The combined light is inputted into an optical divider 160 through a parallel beam lens unit 130. The combined light inputted into the optical divider 160 is incident on an object 190 including a step composed of two different metals through an object lens unit 140. The incident combined light is reflected from the object to be transmitted to an interferogram acquisition unit 180 through the object lens unit 140, the optical divider 160 and an image lens unit 170, thereby obtaining the white-light interferogram.

The two illuminating lights used for the experiment using the apparatus have their central wavelengths, $\lambda_1 = 650nm$ and $\lambda_2 = 550nm$ and the bandwidth $\Delta\lambda = 70nm$. The illuminating lights are used in order to solve the problem of the conventional white-light interferometry that the white-light interferometry is difficult to divide a specific wavelength component and vulnerable to external disturbance because it includes all of the visual ray range. The white-light interferogram generated from the illuminating lights is as shown in FIG. 7A. FIG. 7B shows the spectrum obtained by Fourier-transforming the white-light interferogram. In the spectrum of the interferogram shown in FIG. 7B, peaks appear at the central wavelengths of the two illuminating lights, $\lambda_1 = 650nm$ and $\lambda_2 = 550nm$, as expected. It can be confirmed that the illuminating lights are not affected by external disturbance because the lights are concentrated on the specific wavelengths λ_1 and λ_2.

As shown in FIG. 7A, the algorithm for detecting peaks on the space is not suitable

for detecting the envelope peak of the two-wavelength white-light interferogram. (Reference with respect to the algorithm is invited to the article entitled "Wavelet transform as a processing tool in white-light interferometry" by P. Sandoz appearing in Otp. Lett, 22, 1065 (1997), which is not explained in detail in the present invention.) However, frequency domain analysis that is an algorithm proposed by Groot is suitable for detecting the envelope peak from the two-wavelength white-light interferogram because it Fourier-transforms the obtained interferogram to use the phase at each frequency. In the present invention, detailed explanation for the frequency domain analysis is omitted and reference is invited to the article entitled "Three-dimensional imaging by sub-Nyquist sampling of white-light interferograms" in Opt. Lett, 18, 1462 (1993).

When the obtained white-light interferogram I(z) is Fourier-transformed into J(k)=FFT[I(z)], the phase at the frequency domain has the following relationship.

$$\angle J(k) = \phi(k) - 2(k - k_0)z_m \qquad \text{(Equation 14)}$$

From Equation 14, it can be known that the envelope peak z_m is identical to the slope value with respect to the frequency k and phase changes ϕ_1 and ϕ_2 can be calculated at frequencies k_1 and k_2 arbitrarily set.

In application of the above-described details on the measuring system, the phases $\phi_1(k_1)$ and $\phi_1(k_2)$ of the two frequencies $k_1(=2\pi/\lambda_1)$ and $k_2(=2\pi/\lambda_2)$ are first calculated in the spectrum of FIG. 7B to extract two fringe peaks, and then slope values are calculated from all phases in the domains the two frequencies include to extract the envelope peak. Accordingly, the frequency domain analysis is applied to the interferogram obtained from the two-wavelength white-light interferometer, as described above, to calculate all of h_1, h_2, H and h with only one-time measurement.

Table 1 represents measurement results of a step height of metals using the two-wavelength white-light interferometry. Samples used for measurements include a 94.0nm standard step sample and a step sample composed of chrome and gold coated on a glass,

which are fabricated in VLSI Co., an expert at making metal step samples, and guaranteed by NIST. The step heights of chrome and gold were measured by a contact measurement instrument and they were confirmed to have 76.0nm and 67.0nm, respectively. The step heights H, h_1 and h_2 measured using the envelope peak and two fringe peaks obtained from the two-wavelength interferogram are represented in Table 1, and the measured step height h self-corrected is calculated from H, h_1 and h_2 as 95.3nm, 71.9nm and 60.4nm. The measuring errors are 1.3nm, 4.1nm and 6.4nm, respectively. Especially, the step height of the 94.0nm standard sample composed of two different metals has the small error value of 1.3nm. The measurement result of the standard sample is shown in FIG. 8. From the aforementioned experimental results, the measuring error of tens of nanometers, generated when the height of the step composed of different metals is measured by the conventional optical phase interferometry, can be reduced to several nanometers by using the two-wavelength white-light interferometry proposed by the present invention.

What is claimed is:

1. A two-wavelength white-light measurement method for measuring the height h of a step composed of different metals, comprising the steps of:

combining a first light whose frequency is k_1 and a second light whose frequency is k_2 with each other;

inputting the combined two-wavelength white light into the step of the different metals, to obtain an interferogram;

acquiring a step height value H through fringe peaks of the interferogram;

Fourier-transforming the interferogram through frequency domain analysis;

obtaining a step height value h_1 at the frequency k_1 through the result of Fourier transform;

acquiring a step height value h_2 at the frequency k_2 through the result of Fourier transform; and

introducing the obtained H, h_1, h_2 and the central frequency k_0 of the combined two-wavelength white light into the following expression.

$$h = H - \frac{1}{2}\frac{k_0(h_2 - h_1)}{k_2 - k_1}$$

2. The two-wavelength white-light measurement method for measuring the height h of a step composed of different metals as claimed in claim 1, wherein the frequencies k_1 and k_2 are different from each other.

3. The two-wavelength white-light measurement method for measuring the height h of a step composed of different metals as claimed in claim 1, wherein the first light has the central frequency k_1 and a predetermined bandwidth, and the second light has the central frequency k_2 and a predetermined bandwidth.

4. A two-wavelength white light interferometer for measuring the height h of a step composed of different metals, comprising:

an optical combiner(120) for combining a first light having the central frequency k_1 and a predetermined bandwidth and a second light having the central frequency k_2 and a predetermined bandwidth with each other, to make a two-wavelength white light;.

a parallel beam lens unit(130) for changing the combined light into parallel light;

an optical divider(160) for dividing the light outputted from the parallel beam lens unit;

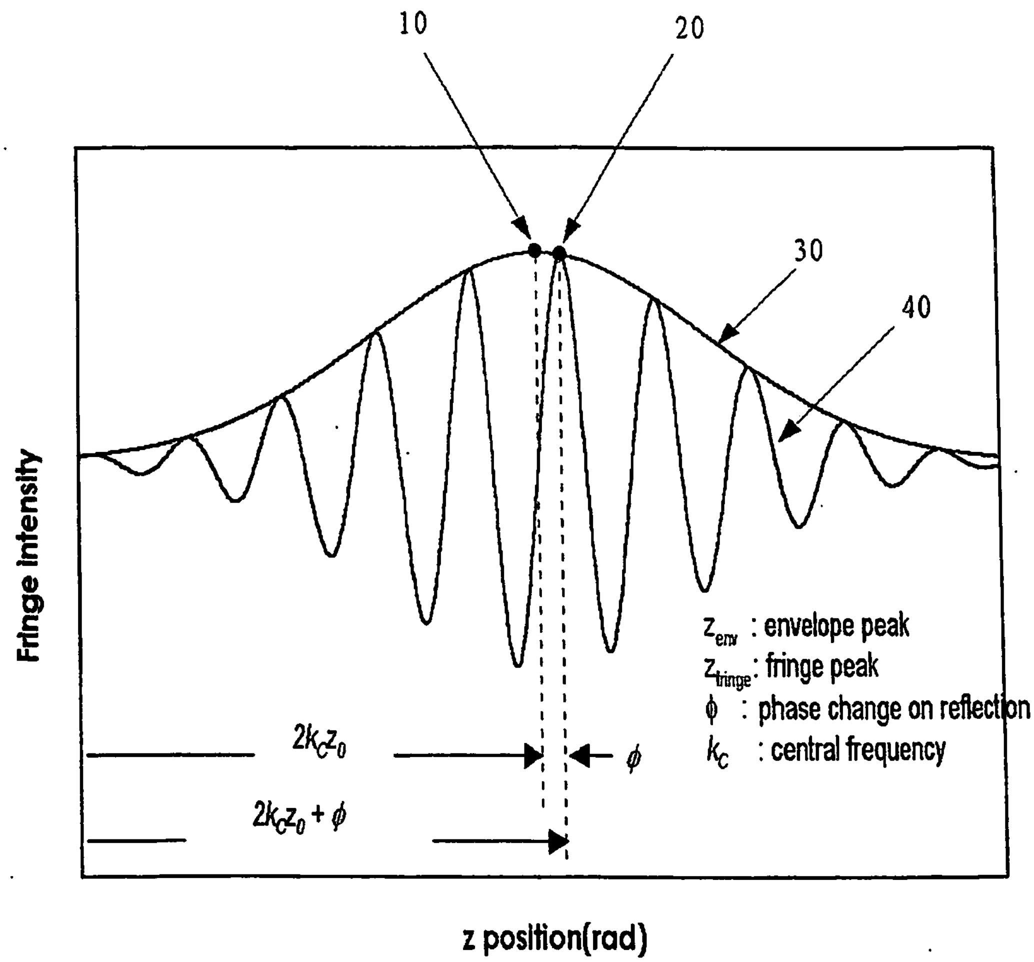
an object lens unit(140) for inputting the light emitted from the optical divider into an object(190) to be measured;

an interferogram acquisition unit(180) for acquiring the light that has been inputted into the object and then reflected; and

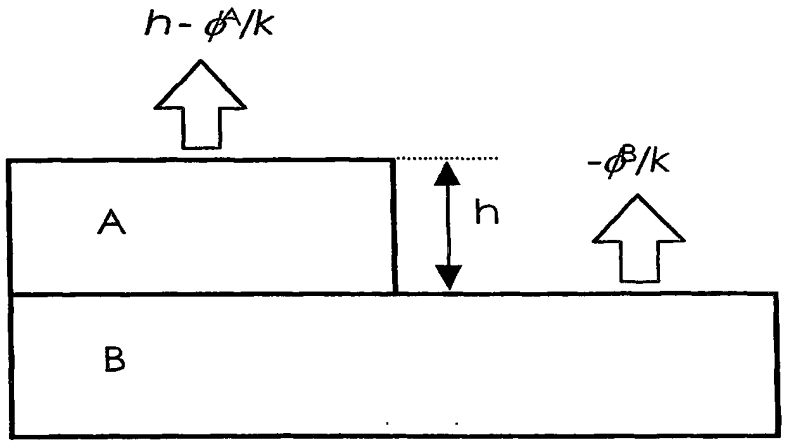
the object lens unit(140) and an image lens unit(170) for inputting the reflected light to the interferogram acquisition unit(180).

[FIGURE]

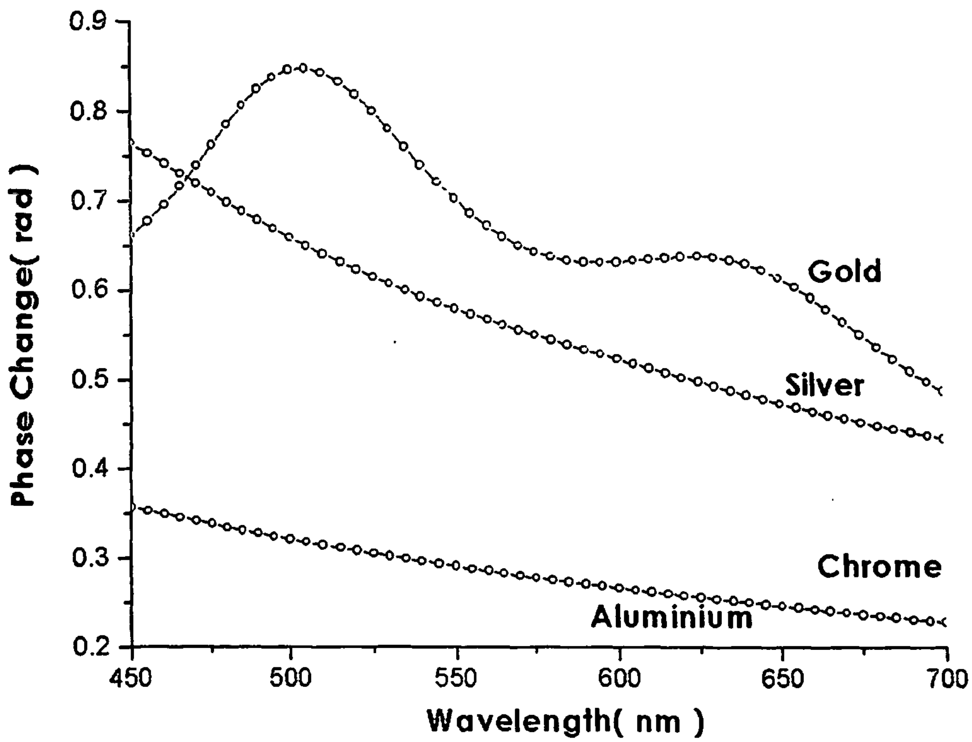
[FIG 1]


10
20
30
40
Fringe Intensity
z_{env} : envelope peak
z_{fringe} : fringe peak
ϕ : phase change on reflection
k_C : central frequency
$2k_Cz_0$
ϕ
$2k_Cz_0 + \phi$
z position(rad)

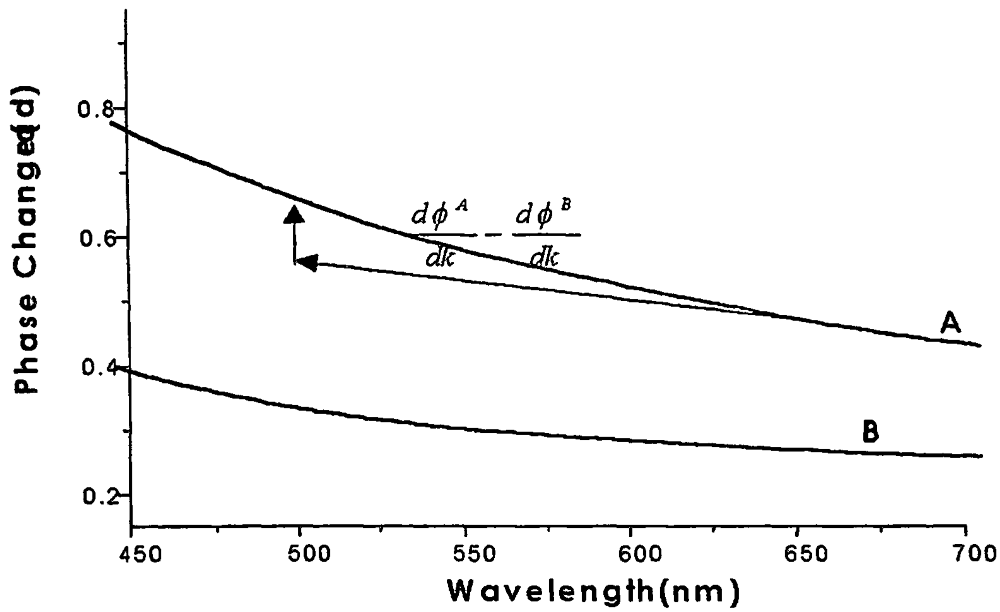
【FIG 2】



[FIG 3]

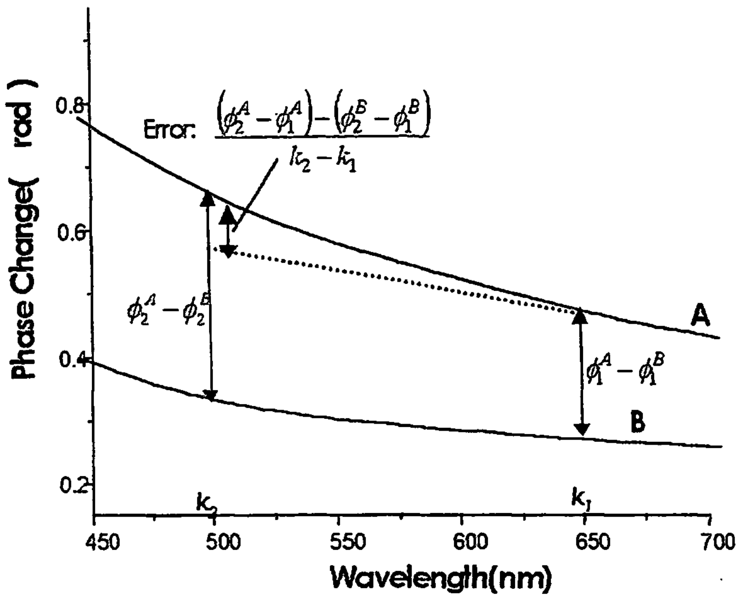

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Phase Change(rad)
450
500
550
600
650
700
Wavelength(nm)
Gold
Silver
Chrome
Aluminium

[FIG 4a]



Phase change error caused by two metals A and B : $\frac{d\phi^A}{dk} - \frac{d\phi^B}{dk}$

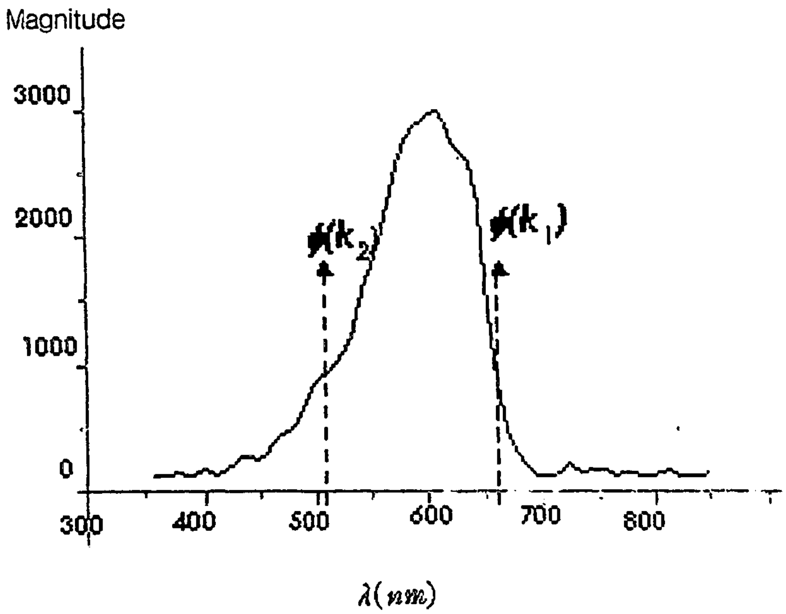
【FIG 4b】



Calculation of the phase change error using the measuring error of monochrome light interferometry $(k_1=2\pi/\lambda_1, k_2=2\pi/\lambda_2)$ Interpretation of the error caused by the envelope peak

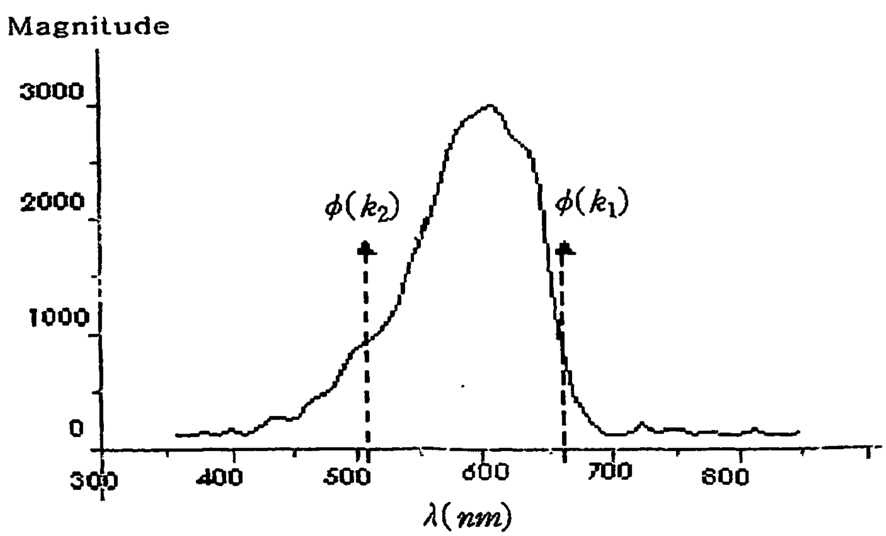
$Z_\phi(=\frac{1}{2}d\frac{\phi}{dk})$

【도 5a】



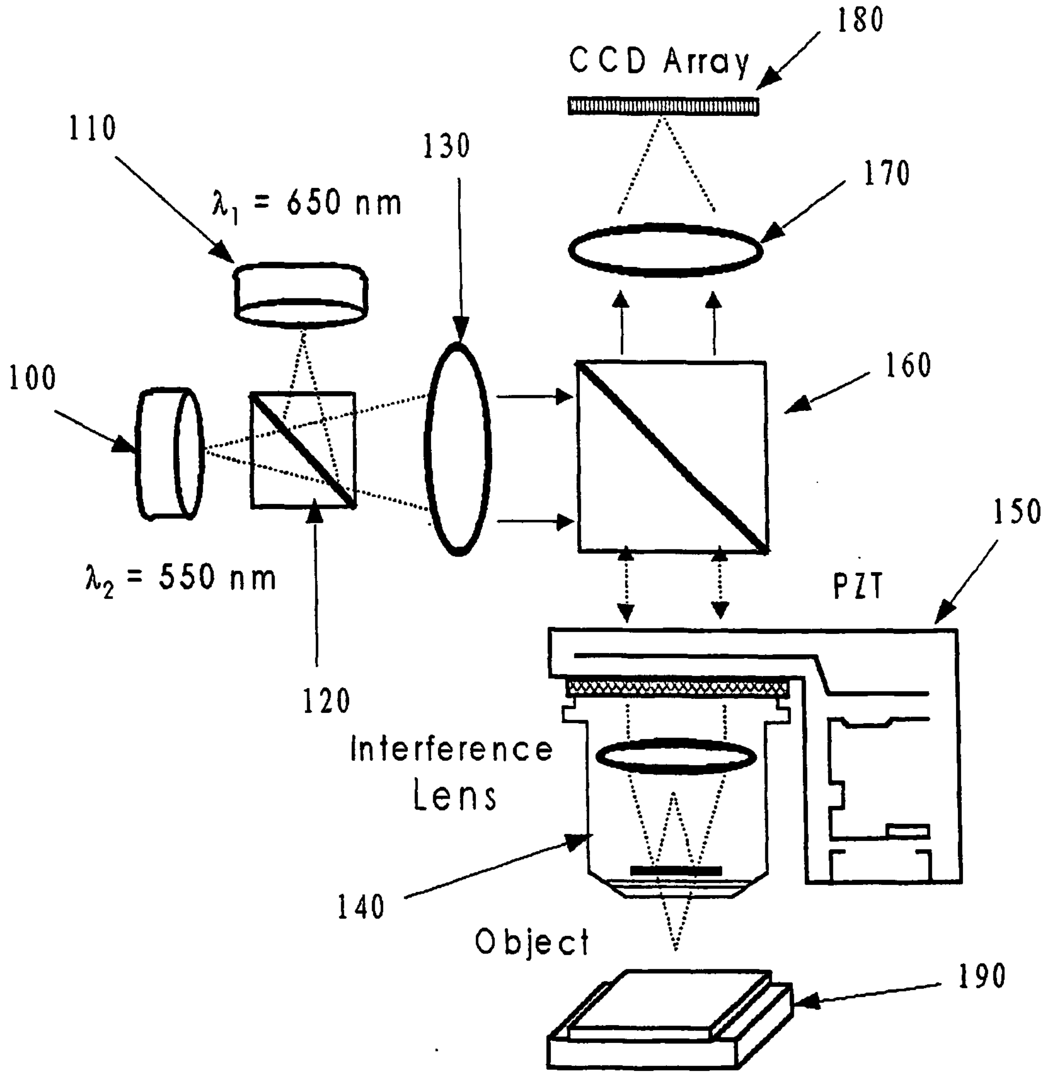
White-light interferogram

【도 5b】



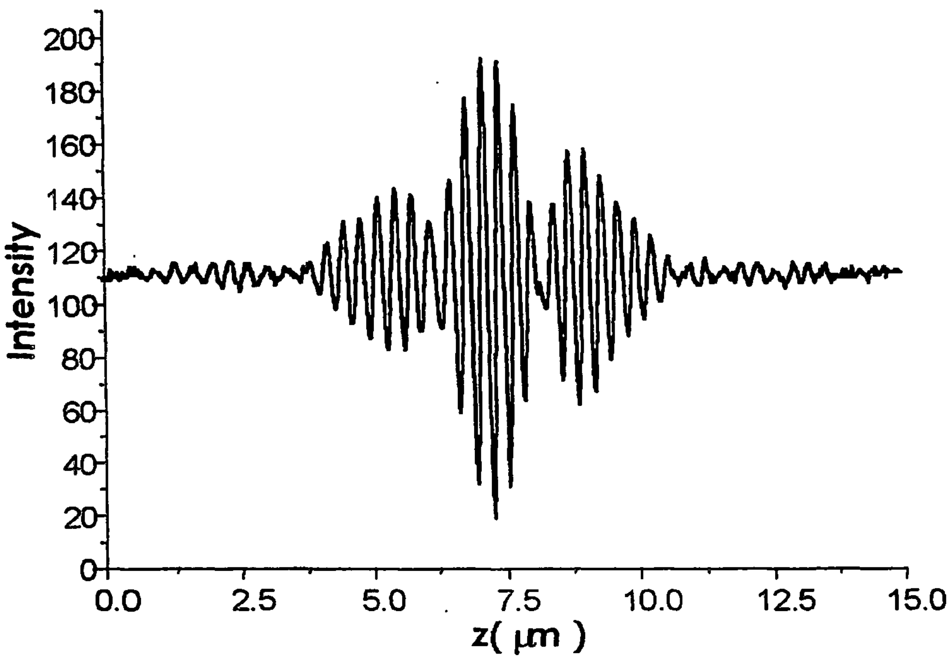
Result of Fourier transform of the white-light interferogram

【도 6】

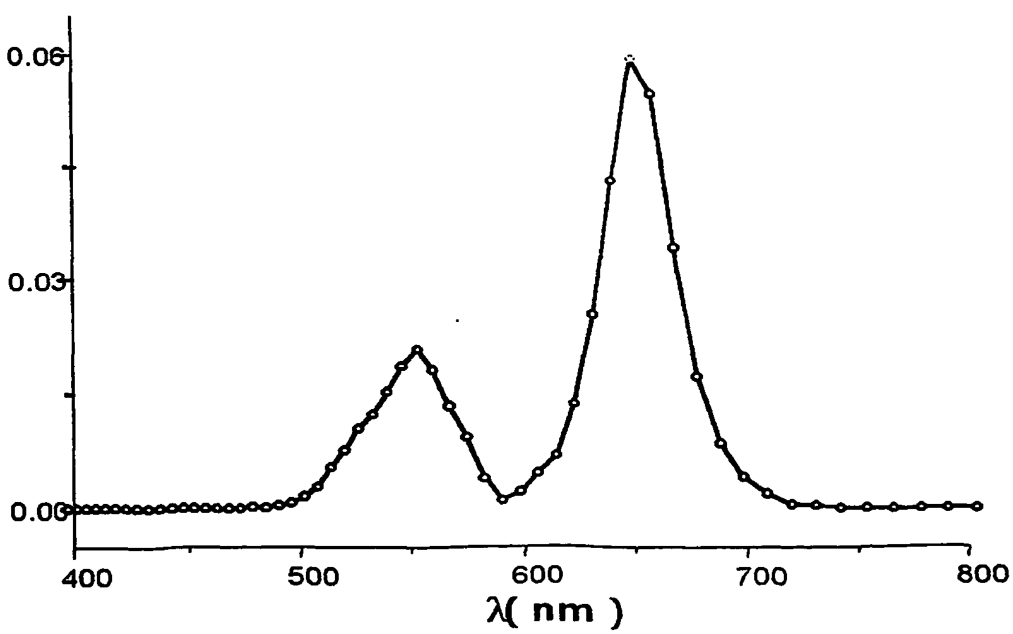


180
CCD Array
110
130
170
λ_1 = 650 nm
100
160
150
λ_2 = 550 nm
PZT
120
Interference Lens
140
Object
190

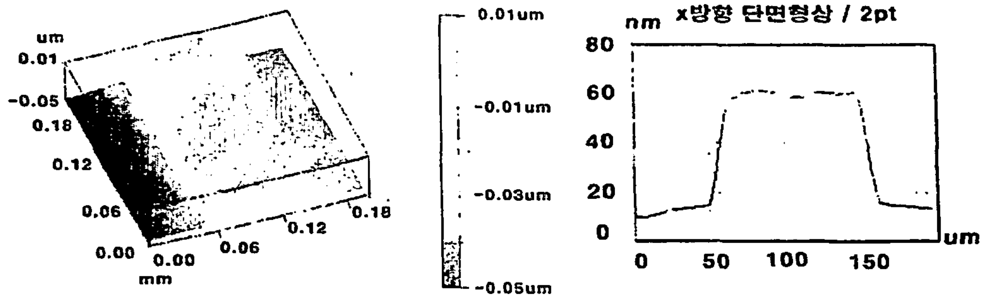
【도 7a】


Intensity
200
180
160
140
120
100
80
60
40
20
0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
z(μm)

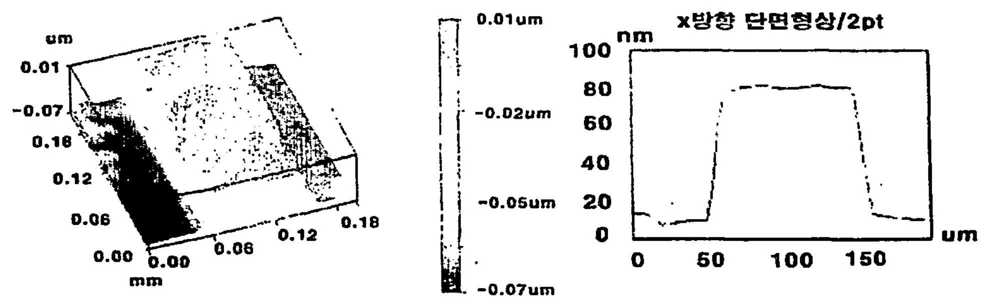
【도 7b】


0.06
0.03
0.00
400
500
600
700
800
λ(nm)

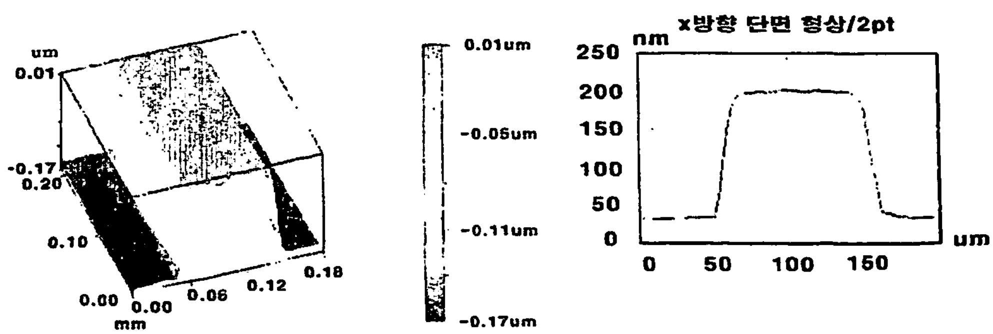
【도8】



(a)Result of calculation of fringe peak , $\lambda_1 = 650nm$, $h_1=45.5nm$



(b)Result of calculation of fringe peak , $\lambda_2 = 550nm$, $h_2=68.2nm$



(c)Result of calculation of envelope peak , H=162.9nm

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR02/00609

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G01B 9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7 G01B 9/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Patents and applications for inventions since 1975, Korean Utility models and for utility models since 1975,
Japanese Utility models and for utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 62- 257010 A (TOSHIBA CORP) 9 November, 1987 (see the whole documents)	1 - 4
Y	JP 03 -0160307 A (MATSUSHITA ELECTRIC IND CO LTD) 10 July, 1991 (see the whole documents)	1 - 4
Y	JP 11- 287628 A (OMRON CORP) 19 October, 1999 (see the whole documents)	1 - 4
Y	US 5,555,471 A (Wyko Corp) 10 September, 1996 (see the whole documents)	1 - 4

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
"E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevence; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 JULY 2002 (23.07.2002)	23 JULY 2002 (23.07.2002)

Name and mailing address of the ISA/KR	Authorized officer
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